THE INVERTEBRATES OF BISCAYNE BAY

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ABSTRACT

The marine invertebrates of Biscayne Bay are living under stress over most parts of the bay, and many populations have been decimated through shoreline changes, reduced flushing, sea grass destruction, and various forms of pollution. Comparisons between life on natural rocky shores, in rip-rap, and on vertical bulkheads show that the latter is the least desirable as a man-made structure. The sea grass communities are the richest known and their removal through various causes has greatly reduced invertebrate numbers in the bay.

Recommendations for the revitalization of the bay include shoreline restoration by natural landscaping and rip-rap, increased flushing by widening channels through the causeways or construction of new water flow channels, and replanting of barren bay bottom with marine grasses. Pollution must be continually reduced, as no known tolerance levels of bay invertebrates can be used for determining safety criteria. Pesticide problems in south Dade canals must be resolved. A broad scale survey of the invertebrates of the bay is required as baseline studies for proper bay management.

INTRODUCTION

Biscayne Bay lies at the meeting place of the tropical West Indian Faunal Province and the temperate Carolinian Faunal Province. As a result it has a very rich invertebrate fauna. Despite its unique position its fauna has never been adequately surveyed and no species inventory is available. A review of the older accounts of Biscyane Bay and the surrounding region reveals nothing of importance concerning the invertebrate fauna, and even taxonomic lists prior to the establishment of the University of Miami yield no information on distributions and numbers.

As a result, we are forced to rely for information about the original fauna on rather general statements in the early literature, especially on the ecological conditions then existing. Recently, for instance, it was suggested at a public hearing that the north end of the Bay was formerly a freshwater marsh and that perhaps the recovery of the north Bay area would be aided if this part of the Bay cound be returned to its supposed freshwater condition. Fortunately, this statement cannot be substantiated. The earliest reports known on the Bay show that the north end was lined with dense stands of mangroves, which cannot live in fresh water. In 1881 Dumbfoundling Bay was a mangrove-lined brackish water mud pond with mud so deep that it was almost impossible to pole across it (Pierce, ms.). Biscayne Creek was a narrow mangrove lined estuary which entered into the north end of the Bay beyond which the entire nature of the water changed. From there southward the aspect was of beautiful sea green waters of the old unpolluted Bay and the Keys. The bottom varied from white or gray marl supporting meadows of marine grasses to hard rocky bars on which grew a large variety of sessile organisms including sponges, small corals, alcyonarians, and other residents of clear, clean seawater.

Hobart Smith (1896) surveyed Biscayne Bay as the possible site of a government fish hatchery and experiment station and stated "The water of Biscayne Bay is exceedingly clear. In no part can one fail to clearly distinguish objects on the bottom when the surface is not especially rough. It seldon becomes roily, and the amount of muddy water brought down from the Everglades is too small to have any noticeable effect on the clearness of the Bay."

In the early 1900's the first of the dredgings occurred which brought the fresh waters of the Everglades into Biscayne Bay. These had detrimental effects upon the fauna almost from the beginning. No one has documented these but besides bringing in a continuous flow of freshwater, the waters brought with them sawgrass rootlets and hairs. These sink to the bottom and form dense mats which smother the bottom forms and infauna. A case of this occurred in Lake Worth in 1946 when the high waters in the Everglades brought in such a load of rootlets and hairs that the bottom life in the lower end of the lake was killed off for several years. It slowly came back only as the fur-like matting was finally flushed out to sea.

Other factors which have effected the numbers and distribution of invertebrates in the Bay have been the construction of the various channels for vessels, the erection of large islands in the Bay, and the building of the major causeways , all of which have resulted in severe reduction of water flow and the resultant reduction of the flushing rate. This is especially true in the northern half of the Bay where the most drastic effects can be seen. The accompanying vertical concrete seawalling of the shoreline has eliminated the natural filtering of the land run-off and increased turbidity. This in turn helped in the extensive reduction of the shallow-water marine grass beds which afford one of the richest invertebrate habitats known. Finally, sewage and pesticide pollution of the Bay waters accomplished what all of the other activities could not; they removed large segments of the Bay from habitation by useful and desirable life forms. Many of the changes have been documented by Thorhaug in this symposium.

The first studies of the distributions of marine life in the Bay and descriptions of life zones were by Pearson (1936) in conjunction with his undergraduate course in marine biology and dealt with the kinds and numbers of brittlestars. This was followed by a similar paper by Deichmann (1938) on the sea cucumbers and Smith (1943) on the corals. In 1948 Weiss published the results of his studies of the seasonal occurrence of sedentary fouling organisms in the Bay. The first ecological study was that of Smith _et al._ (1950) which dealt primarily with hydrography and chemistry and secondarily with plankton numbers. Stephenson and Stephenson (1950) touched upon the Bay in their basic study of the ecology of the Florida Keys. In 1955 Voss and Voss published their study of the ecology of Soldier Key which has served too often as the basis for comments upon an unpolluted Bay area. D. Moore discussed the fauna associated with turtlegrass (1963). McNulty _et al._ (1962a, 1962b) reported upon the level seabottom communities of the middle part of the Bay south of Rickenbacker Causeway, while in 1967 O'Gower and Wacasey published upon the animal communities associated with turtle grass and shoal grass. Voss _et al._ (1969) prepared a report on the waters of the proposed Biscayne National Monument which included all information obtainable to that time on the invertebrates of the southern portion of Biscayne Bay. This included a list of the species known at that time from the region. Since 1969 numerous reports and preliminary reports have dealt with the invertebrate fauna of various portions of Biscayne Bay from various aspects as the need has arisen in in conjunction with industry and development. Some of the findings are of excellent quality; others are of dubious value. It can be definitely stated, however, that at present no solid baseline studies of the invertebrate fauna of any part of the Bay have been conducted with sufficient expertise and with a sufficient variety of sampling gear to give an adequate picture of the invertebrate fauna of any region. Even McNulty's pollution studies (1970) were not based upon sufficiently diverse gear to give the results which are now needed for an assessment of the invertebrate life of the area studied or its total change.

DISCUSSION

It will probably be more useful to survey the faunas from a zonation and habitat viewpoint. This will also permit better understanding of the problems and priorities. Later changes can be reviewed from the standpoint of what has caused them and how they can be overcome or reversed.

Intertidal Fauna

Rocky. The tidal range in Biscayne Bay averages 1.9 feet with a spring range of 2.3 feet. This is a rather typical tidal range for tropical areas and greatly reduces the amount of living space for intertidal animals in contrast with areas in high latitudes which may have mean ranges from 12 to 30 feet, or open coastal areas where wave action may widen the band (Voss and Voss, 1960). Thus the vertical range of intertidal life is restricted to these figures except where wave action in the bay may extend them upward slightly.

Under natural shoreline conditions in Biscayne Bay, however, this vertical range was supplemented by the slope of the shoreline. On Soldier Key, for example, the lower platform extends outward and was exposed for up to 12 feet. Behind the lower platform is an eroded platform face which is narrow and vertical and which occupies much of the vertical range, followed by a very gently sloping upper platform which in some areas extends shoreward 20 to 30 feet and is covered by water at high tide. Thus on a natural rocky shore the intertidal area available for attachment or safety of the fauna was a band varying from perhaps as much as 10 to 50 feet. This was occupied by a wide variety of animals. It included numerous bryozoans, hydroids, tunicates, anemones, gastropods, chitons, mussels, sponges, echinoderms, crustaceans, and others. Also, numerous swimming forms such as shrimp lived in large numbers in the small tidepools existing in the eroded limestone. This type of habitat is densely inhabited. Counts of the animals occurring on a meter square surface ran into the hundreds per species, especially among such forms as mussels, barnacles, and false limpets.

Another type of rocky intertidal habitat is shown by a boulder shore exemplified by the jetties inside Government Cut and areas along the MacArthur and Venetian causeways. While the vertical range is smaller in parts because of a more protected location, the volume is great because of the extensive crevices, holes, and caverns found among the boulders in these structures. These afford not only greater attachment space for sessile animals but security for smaller invertebrates for brooding eggs or depositing them and protection for the eggs until hatching.

These two types of rocky shores may be contrasted with the vertical concrete surfaces of seawalls which are so prevalent throughout the Bay, especially in the northern half. Two areas were recently surveyed by the writer: Fair Isle south of Rickenbacker Causeway and a seawall in Biscayne Creek just north of the 163rd Street Causeway.

At Fair Isle the northwest seawall, which is protected from wave action, has a band of sessile organisms extending from the foot of the wall, just below mean low water, to above the high water mark covering a bond about 3 feet wide. This zone is composed mainly of barnacles, a few common oysters near the low tide mark, and some algal mats and mats of bright orange sponge below the low tide mark. Scattered among the barnacles were a few false limpets Siphonaria, the small Nerita, and above the high water mark the snail Littorina angulifera. Running over the face of the seawall were hundreds of the isopod Ligida, and a few Grapsoid crabs.

On the southwest end there was more wave action and the number of animals increased. Nerita was less numerous and its place was gradually taken over by the snail Thais. Littorina angulifera disappeared but its place was taken by L. ziczac which prefers a more exposed habitat. There were also a few horse conchs.

The offshore side of the seawall was more exposed and the zone here was expanded to a height of about 5 feet. All of the previously listed species were present except Nerita and Littorina angulifera. The growths of sponges and attached algae were denser and the oyster population larger.

A similarly constructed seawall in Biscayne Creek had an active intertidal assemblage occupying a zone only about 2 feet high. The vertical face was composed of solidly compacted oysters, Crassostrea, with a narrow band of the false limpet Siphonaria intermixed with large numbers of the small, black shell-less mollusk Onchidella. A few snails, Littorina angulifera, were found adhering to the wall above the high tide mark and a few isopods ranged over the face. The area is entirely protected and the band represented the tidal range.

Mangroves. Much of the original shoreline of Biscayne Bay, especially in the northern end and south Bay, and back of the Sand Keys, was fringed with mangroves. It might be well to point out here that the presence of mangroves in an area now does not necessarily mean that the area has long had them. When the first settlers came to Lake Worth in the mid-1870's there were no mangroves on its shores. It was not until an inlet was dug by shovel in the 1880's that mangroves appeared, but by 1930 much of the shore of the lake was heavily covered with mangroves so that recently it has been suggested that the lake originally was surrounded by mangroves.

Mangroves not only offer a substrate for attachment and a refuge for a host of animals but they also contribute to both the enrichment of the Bay by decomposition of their leaves and to the filtration of ground water run-off into the Bay. The prop roots of the red mangrove in the southern part of the Bay are typical of the growth that may be found in relatively unpolluted areas and consist of not only the prop roots proper but also massive accumulations of algae and sessile and crawling animals, the mass of the roots being increased several times by their accumulated life. In the south end of the Bay and especially along the seaward side, the growth on the roots consists of masses of red algae, tunicates, sponges, several kinds of oysters, barnacles, the snail Littorina, false limpets, Nerita, the crabs Pachygrapsus and Sesarma, several species of isopods, melampid snails, hydroids, and bryozoans.

In the northern part of the Bay, the major invertebrates found on the roots of the red mangrove consist mainly of the oyster Crassostrea. Most of the other forms named are missing except for the boring gribble, Sphaeroma tenebrans, which is present in considerable numbers.

Sandy and Muddy Shores. Under normal conditions these shores contain numerous burrowing animals such as the fiddler crab Uca, various marine annelids, and several common mollusks. Few of these beaches are left in the Bay and most of them are artificial in that they have been formed by dredging. Most occur in south Bay on the landward side and along Rickenbacker Causeway. They are not highly productive of invertebrates except for the microscopic meiofauna occupying the interstitial spaces in the sand. These have not been well studied in the Bay.

Shallow Water Benthos

Grass Beds. Originally most of the Bay was covered with grass beds, primarily of the turtlegrass Thalassia but with mixtures and small pure stands of the other tropical species. In order for these to grow, they must, however, be within the zone of illumination. In clear unpolluted waters, turtlegrass may grow to a depth of at least 30 or 40 feet. Before dredging, the depth of the Bay in no region was too deep for the growth of these grasses. At present the distribution of turtlegrass is becoming rather limited in the Bay, especially in the northern part where channels and borrow areas have lowered the bottom below the zone of light penetration and particularly the compensation depth which itself has become shallower because of the greatly increased turbidity of the water. In the middle and northern parts of the Bay, turtlegrass does not generally grow in depths much below 5 or 6 feet and even then it is rather sparse.

The diminution of the grass beds has had a dramatic effect upon the numbers and kinds of marine life. Studies in the 1960's by the writer assisted by Dr. D. Moore and Mr. R. Work were directed toward determining the kinds and amount of life in the turtlegrass communities of Biscayne Bay. Our studies tended to show that the turtlegrass community was one of the richest, if not the richest, marine community in the world, both in the diversity of life and its numbers. The proliferation of broad, thin leaves greatly increases the available attachment surface for sessile organisms; the leaves and stalks form a refuge for innumerable swimming and crawling forms; the deep root mass binds the substrate and forms further refuge for burrowing animals. The leaves serve as sediment traps and aid in the clarification of the water. The total assemblage forms such a rich source of food, that the grass beds are nursery grounds for many of our most important food and game fish.

No final count can be given here of the number of species found inhabiting this community but Dr. D. Moore (unpublished data) found over 20,000 specimens of only three species of mollusks per square meter of turtlegrass bottom near Matheson Hammock. The well-being of this community of animals is important to the security of the bait shrimp and spiny lobster fisheries as well as those of many sport fish.

Hard Bottom Communities. The hard bottom areas north of the MacArthur Causeway have largely been covered over by silt, and the turbidity is such that life conditions are not good. Those south of the Rickenbacker Causeway are still in fairly good condition, even as far north as Mashta Point. The growth on these rocky or hard bottom bars consists primarily of sponges, alcyonarians, various inshore corals, red and green algae, and many and varied species of invertebrates which live in, on, and around the others and in rocky holes and crevices. Among these are the stone crab and the spiny lobster.

Our 1969 survey showed that this habitat was under stress on the western side of the Bay as indicated by numerous alcyonarians with partially exposed skeletons overgrown with algae and similarly half-dead sponges. On the eastern side near Elliott Key these same species seemed to be healthy and growing more luxuriantly; no missing polyps were noted and little infestation with algae was seen. Whether the condition noted on the western side was due to the hot water run-off from the Turkey Point Power plant, the effluent from the drainage canals, or pollution in general, could not be determined in the scope of our study.

Soft Bottom Communities. Studies conducted during the 1960's by personnel of the University of Miami included sampling the faunas of the level sea-bottom communities in Biscayne Bay. Reports by McNulty et al. (1962a, 1962b) showed that the level sea-bottom communities, consisting mainly of infauna, in the middle part of the bay and opposite Bear Cut and Cape Florida channel were comparable in numbers, types, and associations with those described from other areas of the world by Gunnar Thorson and his disciples. These communities were quite rich and were found in the open marl bottom. These types of bottom do not seem today to be as rich around the areas of Mercy Hospital and Fair Isle, but this bottom has been disturbed by dredging.

A soft bottom area was studied in Biscayne Creek. It was found to be greatly improverished in species, and only the golden tube worm, Cistenides, was present in any numbers. Two grab samples revealed only one tube worm and several minute crustaceans.

This brief survey of the general condition of the invertebrates of Biscayne Bay may now be useful in looking at some of the changes which have occurred, and in trying to determine their causes.

Pesticides

It is difficult to assess the effects of pesticides upon the invertebrates of the Bay. No monitoring has been done at canal mouths for anything but fishes; fish kills have often been reported at the mouths of drainage canals in south Dade County. These have been directly associated with the practice of rinsing out spray trucks and tanks, and even the discard of pesticide sacks into the canals from the adjacent farm lands. For some peculiar reason, most of the concerned agencies seem to think that only fish warrant their attention, and no invertebrate worker is ever alerted when a kill is announced. Partly this is due to the fact that dead fish float and are more visible, while invertebrates, having no swim bladder, sink. The Hoover Committee report of 1969, drew the County's attention to the pesticide problem in south Dade and asked that the area be put under surveillance. The problem still exists but in a somewhat different form. There is no reason to think that the invertebrates have not been as seriously affected as the fish.

When the State of Florida sprayed Dade County in the 1960's in an effort to eradicate the Mediterranean fruit fly, the spray planes started their work at the water's edge. Within minutes of the passage of the first plane along the Bay shore, complaints began to come in of heavy mortality of young tarpon and pompano. Within a few hours the ocean beach from Miami to Palm Beach had a windrow of dead sand fleas, Emerita, about 2 feet wide and several inches deep that stretched in an unbroken line the entire length of the beach. Sand fleas were almost completely exterminated from the beaches for several years with a resultant decline in the sport catch of pompano and other fish which feed upon these invertebrates and for which they are used as bait.

One has to assume that most of the invertebrates killed by pesticides are then eaten by predators, probably with further ill effects along the line. It is entirely possible that the poor condition of the alcyonarians and sponges on the west side of the Bay, noted in the Biscayne National Monument report, could have been due to this cause. We have, however, no proof of the causitive agent.

Dredge and Fill

Many of the problems we now encounter concerning the invertebrate life in Biscayne Bay are due to dredge and fill activities, either directly or indirectly. Direct effect, of course, is the removal of the animals and the bottom in which they live, the covering over of the bottom and the animals, smothering of adjacent areas by the sediments, and the erosion of the fill areas before stabilization. Indirect effects have been the constriction of water flow by artificial islands and causeways, thus reducing flushing, and creation of stagnant bottoms in channels and borrow pits. These are too deep to be flushed by wave action and the bottom is too deep for the growth of marine grasses. It is these direct and indirect effects which have done much to lower the viability of the north end of the Bay and will harm the south end if permitted to occur under the plea of social exigency.

Bulkheading

Almost without exception the type of bulkheads used in Biscayne Bay have been of the conventional vertical concrete design. These of course are equivalent to rocky shores but they have the distinct disadvantage that, being vertical, they afford the least possible living space and refuge for animal life. Of the three types of hard substrate shores described above (seawalls, boulders, and natural rocky shores) the concrete vertical wall offers the least space for colonization, living, and refuge. In addition, these bulkheads reflect wave action stronger than any other type and thus assist in keeping sediments in suspension, thereby further preventing grasses from colonizing and proliferating and deterring growth in colonial forms of invertebrates.

Sewage and Industrial Pollution

Sewage pollution was a major problem in the middle and north Bay area until the City of Miami installed the new sewage treatment plant on Virginia Key and tied the city sewer system to this, closing the many outfalls. Prior to this, in the 1950's and before, the sewage of the city of Miami was dumped without treatment directly into the Bay or into the Miami River. McNulty et al. (1960) reported upon their studies showing the ecological conditions at that time and the distribution of coliform bacteria in the Bay. In 1960 McNulty resurveyed the benthos of the Bay and published his results (1970). His studies, carried out mainly by grab samples, showed that considerable changes had occurred. Some of these are interesting as they apply to standing crop and diversity.

On soft bottom in one area there were 21 species with pollution while there were at the same station

14 species without pollution, a dramatic change. However, on the basis of numbers of individuals per square meter it only changed from 88.6 individuals to 81.4, hardly a noticeable difference. In another soft bottom area there were 4 species with intense pollution and 4+ without while there were 9.0 individuals per square meter with pollution and 10.5+ without. An important observation was that with pollution some of the stable members of the community were missing, their places taken by non-community immigrants.

On hard bottom at one station, some distance from an outfall with pollution, there were 46 species compared with 25 without, while the numbers of individuals were 651 and 108. At an area close to the main outfall there were 5 species with pollution and 9 without, while the number of individuals was 18 with pollution and 126 without.

These figures show that while it is true that some fertilization of the waters aids the growth of invertebrates, an excessive amount inhibits it. The question then arises: How much fertilization can an area withstand and still be viable? A further question, and one of far greater importance, is the quality of the epi- and infauna. Are the faunas composed of desirable species which are important members of the food cycles of larger animals or are they themselves undesirable and are indicators of a polluted environment? Often an area may contain large numbers of undesirable species which are not suitable for food or for sport and which do not support such other species.

Great reliance seems to be placed today on the index of species diversity. While some scientists have begun to suspect that not only has this been overworked but is often misleading, many government agencies are still impressed by these figures and in fact require in some instances that species diversity be calculated and included in reports. The question, however, seems to be, with what level of species diversity will we be impressed? Because the species diversity is higher in one area than in another indicate that the area with the higher species diversity is in better shape ecologically than the other? Or does it mean that a large number of pollution-tolerent species have moved into a formerly unpolluted but impoverished area? The natural sequence of such a philosophy is that we may be, and in fact now are, apparently protecting some polluted areas from being cleaned up because they have a reasonable species diversity index. The numbers game can be dangerous if the ground rules have not been properly established.

Restoration

It seems clear, insofar as the invertebrates are concerned, that a much broader and more detailed study of the fauna is required both for baseline studies and for an understanding of the causes of the diminution of populations. This should be done by undertaking a series of transects across the Bay covering all major segments and reaching from the intertidal to the intertidal on each shore. A variety of sampling gear should be used to obtain as complete a picture as possible of the faunas involved. For best results, transects should be started at each end and worked toward the middle, thus affording early comparisons of areas under heavy stress with relatively unpolluted and unchanged areas.

It is obvious from the review that the changes in the shoreline have had serious effects upon the numbers and distribution of intertidal and near shore life. The review clearly shows that rocky shores have great advantages over vertical seawalls. Since it is impossible to restore natural rocky shores, efforts should be made to replace the seawalls with rip-rap which affords the next best habitat. Extensive rip-rap shorelines would also assist in the spread and increase of the spotted spiny lobster which in the Bay area has only been found in this type of habitat. Where possible the shoreline should be landscaped back to a combination of sandy beaches, mangroves, and rocks both for environmental improvement and aesthetic qualities.

Flushing restrictions in the north Bay are serious. The hydrography of the Bay should be studied and Federal assistance obtained to open up the causeways where necessary in order to increase flow and flushing.

The Bay bottom has been partially denuded of marine grasses by dredging. The feasibility of replanting these areas with sea grasses should be examined and, if plausible, planting should begin as soon as possible. Replacing the seawalls with better structures, increasing flushing, and continued efforts to decrease pollution should provide better clarity of seawater, thus encouraging growth of the grasses. As these become better established, they also will serve as filterers, and turbidity in the Bay should be reduced.

All these actions combined should begin the reversal of the trends which have been described here and eventually bring the invertebrate faunas back to a higher level throughout the Bay. It is impossible to return the Bay to its pristine condition or back to full productivity. However, with nursery grounds reestablished over much of the Bay, a change in the macro-fauna should take place and the overall environmental conditions be more conducive to the health and welfare not only of the invertebrates but to that most important of all vertebrates, man.

LITERATURE CITED

Deichmann, Elizabeth. 1938. Holothurians from Biscayne Bay, Florida. Proc. Fla. Acad. Sci 3: 128-137.

Hoover Committee. 1969. Report of the committee on inshore and estuarine pollution. Hoover Committee Report, Hoover Foundation, Miami, Florida. 63 pp. processed.

McNulty, J. Kneeland. 1970. Effects of abatement of domestic sewage pollution on the benthos, volumes of zooplankton, and the fouling organisms of Biscayne Bay, Florida. Stud. Trop. Oceanogr. Miami 9: 1-107.

McNulty, J.K., E. S. Reynolds and S. M. Miller. 1960. Ecological effects of sewage pollution in Biscayne Bay, Florida: distribution of coliforms bacteria, chemical nutrients, and volume of zooplankton. pp. 189-202 in C. M. Tarzwell (Compiler), Biological problems in water pollution. U.S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Tech. Rept. W 60-3, 285 pp.

McNulty, J. K., R. C. Work and H. B. Moore. 1962a. Level sea bottom communities in Biscayne Bay and neighboring areas. Bull. Mar. Sci. Gulf & Carib. 12 (2): 204-233.

McNulty,J. K., R. C. Work and H. B. Moore. 1962b. Some relationships between the infauna of the level bottom and the sediments in south Florida. Bull. Mar. Sci. Gulf & Carib. 12 (3): 322-332.

Moore, Donald R. 1963. Distribution of the sea grass, Thalassia, in the United States. Bull. Mar. Sci. Gulf & Carib. 13 (2): 329-342.

O'Gower, G. K., and U.W. Wacasey. 1967. Animal communities associated with Thalassia, Diplanthera, and sand beds in Biscayne Bay. 1. Analysis of communities in relation to water movements. Bull. Mar. Sci. 17 (1): 175-201.

Pearson, Jay F. W. 1936. Studies on the life zones of marine waters adjacent to Miami, 1. The distribution of the Ophiuroidea. Proc. Fla. Adad. Sci. 1: 66-72.

Pierce, D. L. (manuscript). On the Wings of the Wind. (unpublished). 695 pp.

Smith, F. G. Walton. 1943. Littoral fauna of the Miami area. 1. The Madreporaria. Proc. Fla. Acad. Sci. 6 (1): 41-48.

Smith, F. G. Walton. Robert H. Williams and Charles C. Davis. 1950. An ecological survey of the subtropical inshore waters adjacent to Miami. Ecology. 31 (1): 119-146.

Smith, Hobart M. 1896. Notes on Biscayne Bay, Florida, with reference to its adaptability as the site of a marine hatching and experiment station. Rept. U. S. Fish Comm. Fish and Fisher. 1895: 169-191.

Stephenson, T. A. and Anne Stephenson. 1950. Life between the tide-marks in North America. 1. The Florida Keys. J. Ecology. 38 (2): 354-402.

Voss, Gilbert L. and Nancy A. Voss. 1955. An ecological survey of Soldier Key, Biscayne Bay, Florida. Bull. Mar. Sci. Fulf & Carib. 5 (3): 203-229.

Voss, Gilbert L. and Nancy A. Voss. 1960. An ecological survey of the marine invertebrates of Bimini, Bahamas, with a consideration of their zoogeographic relationships. Bull. Mar. Sci. Gulf & Carib. 10 (1): 96-116.

Voss, G. L., F. M. Bayer, C. R. Robing, M. Gomon and E. T. LaRoe. 1969. The marine ecology of the Biscayne National Monument. Processed Report to the U. S. National Park Service. Univ. of Miami. 128 pp., 40 figs.

Weiss, Charles M. 1948. The seasonal occurrence of sedentary marine organisms in Biscayne Bay, Florida. Ecology 29 (2): 153-172.